Natural England Commissioned Report NECR270

Viability of fish monitoring techniques in inshore areas of the Southwest of England

First published 10 Feb 2020

www.gov.uk/natural-england

Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

As there is limited knowledge of the biodiversity, variability and condition of inshore fish communities around England, there are repercussions for the efficacy of potential management measures, on estimations of Natural Capital values and on their Ecosystem Service value and contribution to societal goods and benefits.

Natural England commissioned a single piece of work with the ultimate aim of producing a detailed and fully costed monitoring plan for the monitoring of inshore fish populations in the SW of England.

This aim has resulted in the production of 3 linked reports;

1. NECR 269 (Franco, A., Nunn, A., Smyth, K., Hänfling, B. and Mazik, K. (2020a)). A review of methods for the monitoring of inshore fish biodiversity.

2. NECR 270 (this report) (Franco, A., Barnard, S. and Smyth, K. (2020b)). An assessment of the viability of fish monitoring techniques for use in a pilot approach in SW England.

3. NECR 271. (Franco, A., Hänfling, B., Young, M. and Elliott, M. (2020c)). Regional monitoring plan for inshore fish communities in the Southwest of England.

It is intended that the outputs of these linked report be used to underpin a trial of inshore fish monitoring in English inshore water, with the eventual aims of seeking to integrate inshore fish monitoring into the wider UK marine biodiversity monitoring programme

This report should be cited as: NECR 270. Franco, A., Barnard, S. and Smyth, K. (2020b). An assessment of the viability of fish monitoring techniques for use in a pilot approach in SW England.

Natural England Project Manager - Mike Young Michael.young@naturalengland.org.uk

Contractor - Institute of Estuarine & Coastal Studies (IECS). The University of Hull.

Further information

This report can be downloaded from the Natural England Access to Evidence Catalogue:

ISBN 978-1-78354-595-7

Viability of fish monitoring techniques in inshore areas of the Southwest of England

Report prepared by

A. Franco, S. Barnard, K. Smyth

13 June 2019

IECS Report No. ZBB871/2-F-2019

Institute of Estuarine & Coastal Studies (IECS)
The University of Hull
Cottingham Road, Hull HU6 7RX UK
Tel: +44 (0)1482 466771 ¦ Fax: +44 (0)1482 466772
E-mail: iecs@hull.ac.uk

Executive summary

This report provides a summary of fish survey methods that could potentially be used to monitor inshore fish communities in the Southwest (SW) of England. It builds on an earlier review of fish monitoring techniques considering the characteristics and constraints of different techniques in terms of species assessed, data quality, logistics and operational requirements (Natural England Commissioned Report: NER269, (Franco et al., 2020a).

The viability of potential monitoring methods (in the context of their practicality, suitability and cost-effectiveness for use in monitoring fish communities) is assessed relative to relevant characteristics of the SW study area (e.g. habitat and environmental characteristics, overall fish resource, uses of the area).

Initial preliminary cost assessments, based on the informed opinion and expert judgment of the authors, were evaluated and integrated during a stakeholder consultation and engagement workshop, and were subsequently used to support the production of a costed plan for the delivery of a holistic, integrated monitoring pilot aimed at characterising the inshore fish communities of the SW of England (Natural England Commissioned Report; NECR 271, (Franco et al., 2020c).

A stepwise, tiered approach was developed to identify those methods suitable for use in the SW study area, based on criteria considered key to the development of a fit-for-purpose, standardised and cost-effective regional monitoring programme. This tiered approach considered the following three elements in sequence:

i. Practicality of using a method in different broad habitat types (as defined based on substratum, energy and depth) and also considering possible environmental concerns (due to impact of the method on the habitat) where specific sensitive habitats such as kelp, seagrass, mäerl, biogenic reefs and sea-pen and burrowing megafauna communities may occur present;
ii. Suitability of the methods considering the specific requirements of the inshore fish monitoring to be designed for the SW region, in particular the monitoring scope (towards the assessment of the entire fish community rather than of individual species) and the spatial scale represented by the data collected with a method;
iii. Cost-effectiveness as assessed using proxies that assess the quality of the data that can be obtained with a method (qualitative v. quantitative) and the use of the method in existing standardised monitoring programmes that allow a wider use of the data thus collected with that method (e.g. temporal comparisons between newly collected and existing data).

A semi-quantitative approach was applied to the assessment, whereby each method was ranked according to the individual criteria (tiers) mentioned above, and the individual scores were combined in an overall ranking that provides a means to prioritise the different methods according to their viability for use in each of different broad habitat types, either in the absence or presence of specific sensitive habitats.

Contents

List of Figures

List of Tables

1. Aim and scope

This document aims to provide a brief summary of potentially viable techniques that could be used to monitor inshore fish communities in the Southwest (SW) of England.

Inshore fish communities are hereby defined to include both commercial and non-commercial species that live predominantly within 6 nautical miles (nm) of the coast, that are dependent on such shallow inshore waters for part of their lifecycle (species using inshore waters as nursery areas) or that use these waters as pathways for migrations (anadromous and catadromous species).

The viability of methods in the context of monitoring fish communities in the SW inshore waters is assessed in terms of their features and constraints relative to the general environmental characteristics of the SW study area. The review of the fish monitoring techniques presented in the Natural England Commissioned Report: NECR 296, (Franco et al. 2020a), and in particular the matrix provided with it ('Fish method review table'), provide the knowledge basis on the main characteristics and constraints of the different techniques in terms of species assessed, data quality, logistics, requirements, and the main data and metrics that can be obtained from them. The environmental characteristics of the SW study area are reviewed in the section below based on information obtained from the UKSeaMap 2018 (JNCC, 2018), the Atlas of UK marine renewable energy resources (BERR, 2008) and other sources (as cited in the text).

1.1 The study region

The SW inshore waters that are considered in this study include estuarine and marine waters (mainly within 6 nm of the coast) along the coast of Cornwall, Devon, Somerset, and Gloucestershire, from Start Point (south Devon) and into the Severn estuary (Somerset and Gloucestershire) (Figure 1, Table 1). This corresponds to the English inshore component of the UK marine region no. 4 (Western English Channel and Celtic Sea), one of the eleven bio-regions into which UK seas have been divided based on physical and biological features, and aligning with EU Water Framework Directive water bodies and with the regions and sub-regions of the EU Marine Strategy Framework Directive (Defra, 2010).

The inshore areas along the SW coast of England are generally shallow areas, with depth never exceeding 100 m, and most of the waters within 6 nmi of the coast are <50 m in depth. Intertidal and very shallow subtidal areas (<5 m) are located nearer the coastline and within estuaries.

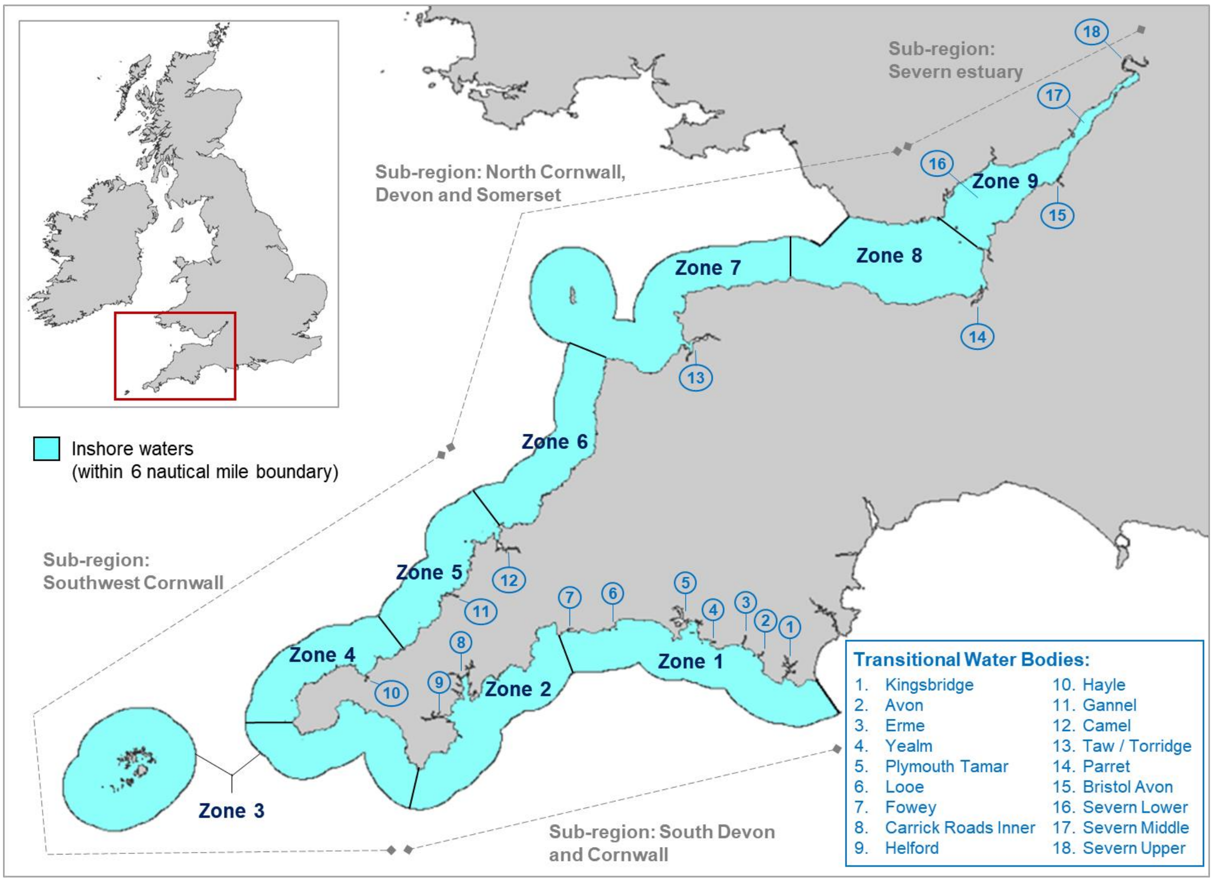

Figure 1. Study region, including coastal waters within 6 nautical miles and transitional water bodies in the SW of England. The subdivision of the region into spatial units (sub-regions and zones) as used for designing the monitoring plan is shown.

Table 1. Geographical scope of the study area and associated sub-units (sub-region and zone). Indicative topographic locations delimiting each inshore spatial unit are given, as well as MPAs (MCZs and SACs) and main transitional water systems (TW) included in each zone (* indicates TW already included in existing WFD fish monitoring undertaken by the Environment Agency).

Region	Sub-region	Zone (port of reference)	MPAs	TW
SW inshore waters [Start Point (South Devon) to Severn Estuary (Somerset and Gloucestershire)]	**South Devon & Cornwall** [Start Point (South Devon) to Lizard Point (South Cornwall)]	**(1) Plymouth** [Start Point (South Devon) to Fowey (South Devon)]	Skerries Bank & Surrounds MCZ Start Point to Plymouth Sound SAC Plymouth Sound and Estuaries SAC (Allis shad) Whitsand and Looe Bay MCZ	Kingsbridge, Avon, Erme, Yealm, Tamar, Looe, Fowey

Table continued…

Region	Sub-region	Zone (port of reference)	MPAs	TW
SW inshore waters [Start Point (South Devon) to Severn Estuary (Somerset and Gloucestershire)]	**South Devon & Cornwall** [Start Point (South Devon) to Lizard Point (South Cornwall)]	**(2) Falmouth** [Fowey (South Devon) to Lizard Point (South Cornwall)]	Fal and Helford SAC The Manacles MCZ Lizard Point SAC	Carrick Roads Inner*, Helford
	SW Cornwall [Lizard Point (South Cornwall) to Camel estuary (West Cornwall)]	**(3) Newlyn/ Penzance** [Lizard Point (South Cornwall) to Land's End (SW Cornwall)]	Lizard Point SAC Mounts Bay MCZ (rock giant goby) Runnel Stone (Land's End) MCZ	
		(4) St. Ives [Land's End (SW Cornwall) to south of Portreath (West Cornwall)]	Lands End and Cape Bank SAC	Hayle
		(5) Newquay /Padstow [south of Portreath (West Cornwall) to Camel estuary (West Cornwall)]	Newquay and the Gannel MCZ (rock giant goby) Padstow Bay and Surrounds MCZ	Gannel, Camel*
	North Cornwall, Devon and Somerset [Camel estuary (West Cornwall) to Lilstock (Somerset)]	**(6) Bude** [Camel estuary (West Cornwall) to Hartland Point (North Cornwall)]	Padstow Bay and Surrounds MCZ Hartland Point to Tintagel MCZ	Camel*
		(7) Ilfracombe/ Bideford [Hartland Point (North Cornwall) to Foreland Point (North Devon)]	Lundy SAC Bideford to Foreland Point MCZ Morte Platform MCZ	Taw Torridge*
		(8) Bridgewater [Foreland Point (North Devon) to Hinkley Point (Somerset)]		Parret

Table continued…

Region	Sub-region	Zone (port of reference)	MPAs	TW
SW inshore waters [Start Point (South Devon) to Severn Estuary (Somerset and Gloucestershire)]	**Severn Estuary** [upstream of Hinkley Point (Somerset and Gloucestershire)]	**(9) Bridgewater/ Bristol** (lower estuary), **Sharpness** (middle and upper estuary) [upstream of Hinkley Point (Somerset and Gloucestershire)]	Severn Estuary SAC (Sea and River lamprey, Twaite shad)	Severn Lower*, Severn Middle*. Severn upper*, Bristol Avon (+ Usk and Wye, Wales)

Tidal ranges in the region generally vary 3.5-5 m, but hydrodynamic conditions in this stretch of coast are heterogeneous, as attested by wave and tidal energy variability (see UKSeaMap 2018, JNCC, 2018; and Atlas of UK marine renewable energy resources, BERR, 2008). In particular, the coastal area along the south coast of Cornwall and Devon is generally characterised by moderate hydrodynamic energy, whereas lower energy conditions characterise estuarine habitats and the marine area in front of the Fal & Helford, and the Carrick Roads estuaries (JNCC, 2018). In this area, higher energy conditions can be found mainly scattered closer to the shore (mostly within 3 km of the coast), with more extensive areas occurring along the south Devon coast and in Cornwall, west of Lizard Point. Tidal ranges around 4-5 m are found along the south coast of Cornwall, with associated lower energy (spring tide peak flow <0.25 m/s) (BERR, 2008).

Conditions that are more dynamic occur along the coast of east and northeast of Cornwall and north Devon, around the Isles of Scilly, and in the outer Severn estuary, with high-energy areas in north Cornwall covering all the inshore waters (JNCC, 2018). Mean spring tidal ranges on the north coast of Cornwall are mostly between 6-7 m, with peak flow generally <1 m/s, whereas tidal energy increases significantly moving towards and into the Severn estuary, where ranges vary between 8 m (estuary mouth) and 12 m (inner estuary), and peak flows are between 2-2.50 m/s. Velocities similar to the latter are also present at Lizard Point and on the easternmost part of Cornwall coast (BERR, 2008).

Substrata in the study region are mostly sandy and coarse sediments, with localised (albeit extensive, on some occasions) areas of rock along the coast and into some estuaries (e.g. Fal and Helford, Plymouth and Tamar, Severn), where muddier sediment components are also present (UKSeaMap 2018, JNCC, 2018). The distribution of substrata appears to correlate with the hydrodynamic conditions, with rocky habitats mainly occurring in the higher energy areas outlined above. Where sedimentary substrata occur, these are mostly sandy along the south and east coast of Cornwall and south Devon, with coarser sediments mostly localised around rock habitats on the coast east of Plymouth, Looe Bay and around Lizard Point (JNCC, 2018). Coarse sediments are more represented along north Devon and in the outer Severn estuary, with wider sandy areas along the coast in between.

Several marine protected areas occur in the SW inshore waters (Table 1), including a range of protected species and habitat features. Migratory fish such as River lamprey, Sea lamprey and Twaite shad (Annex II of the Habitat and Species Directive 92/43/EEC) are the primary reason for the site designation of the Severn Estuary SAC[1], and Allis shad is also a an Annex II species present as a qualifying feature (albeit not a primary reason for the site

[1] http://jncc.defra.gov.uk/protectedsites/sacselection/sac.asp?EUCode=UK0013111

designation) in the Plymouth Sound and Estuaries SAC[2]. Other species as for example the rare Giant goby and Couch's goby (both protected under Schedule 5 of the Wildlife and Countryside Act 1981) occur in the SW, and particularly along the coast of Cornwall (e.g. the presence of the giant goby is reported in the Mounts Bay MCZ[3] and in the Newquay and the Gannel MCZ[4]), and the long snouted seahorse (a protected species under several designations including UK BAP, OSPAR list of threatened and/or declining species and habitats, the Wildlife and Countryside Act 1981, CITES, etc.) also occurs in the region.

Ecosystem engineers (Jones et al., 1994) such as submerged macrophytes[5] (e.g. kelp, seagrass, maërl), reef-forming species[6] (e.g. honeycomb and Ross worm) are of particular interest as they create structurally complex habitats that support taxonomically and functionally diverse biological communities, including fish. These habitats may also be particularly sensitive to impacting activities such as fishing (e.g. bottom trawling), with consequent restrictions in the use of some fishing techniques (e.g. as regulated by IFCAs byelaws), that may be relevant to this viability assessment.

In the study region, large kelp forests are reported to occur inshore within the Annex I habitat 'Reefs' that constitute a primary reason for the designation of both the Start Point to Plymouth Sound & Eddystone SACs and of the Plymouth Sound and Estuaries SAC. They also dominate shallow rocky habitats in the Padstow Bay and Surrounds MCZ, and occur in Lundy MCZ. In all of these instances, bottom towed gear (or demersal mobile gear) is prohibited on, and within 200 m of, reef features (indeed, Lundy MCZ is protected as a no-take zone, whereby all fishing activities are prohibited). Consequently, in all of these areas, the use of fishing gear for monitoring/survey purposes would require dispensation in the form of a scientific licence, granted under byelaw by the Devon & Severn IFCA.

Seagrass (*Zostera marina*) occurs within the Annex I habitat 'Sandbanks which are slightly covered by sea water all the time' which, in turn, constitutes a primary reason for the designation of the Plymouth Sound and Estuaries SAC; seagrass is also present in the shallower part of the Whitsand and Looe Bay MCZ and in Mounts Bay MCZ.

Maërl beds occur in The Manacles MCZ, and an extensive bed of live maërl grows on the St. Mawes Bank in the lower Fal estuary, with extensive areas of maërl gravel also extending throughout the Carrick Roads and Falmouth Bay, in south Cornwall. Rich sublittoral sand invertebrate communities with eelgrass (*Zostera marina*) beds also occur near the mouth of both the Fal and Helford and in some channels of the rias, such as the Percuil River and Passage Cove. Both these features are included as a key habitat within the Annex I habitats 'Large shallow inlet and bays' and 'Sandbanks which are slightly covered by sea water all the time' that constitute primary reasons for the designation of the Fal and Helford SAC. Maërl represents an important habitat that supports overall the marine biodiversity (e.g. through the provision of nursery habitats), but it is very sensitive to physical damage, and generally has poor recovery potential (OSPAR, 2010); consequently the use of bottom-towed gear (dredge or trawl) on maërl grounds is prohibited in The Manacles MCZ (Cornwall IFCA byelaw 2017) and a permission from the local IFCA is required for scientific surveys using these methods.

Biogenic reefs (e.g. Honeycomb worm *Sabellaria alveolata*, Ross worm *Sabellaria spinulosa*) represent another valuable habitat feature that may display sensitivity to the

[2] http://jncc.defra.gov.uk/protectedsites/sacselection/sac.asp?EUCode=UK0013030
[3] https://www.gov.uk/government/publications/marine-conservation-zones-mounts-bay
[4] https://www.gov.uk/government/publications/marine-conservation-zones-newquay-and-the-gannel
[5] http://jncc.defra.gov.uk/page-5804
[6] http://jncc.defra.gov.uk/page-5805

physical effects of benthic or demersal trawling. Within the SW region they occur, for example, in the Hartland Point to Tintagel MCZ, in the Bideford to Foreland Point MCZ, and on the north coast of Devon and Cornwall.

2. Assessment approach

The method review presented in Franco et al. (2020a) has shown that there are a variety of techniques that can be used for monitoring inshore fish communities, but all of them have limitations in their applicability and the type of data they can provide, depending on their selectivity towards certain components of the fish assemblage (e.g. target species, age/size group, morphology type), on operational constraints determined by the habitat characteristics, and on possible licencing restrictions in their use due to their impact on the seabed and the habitats. The detailed assessment of available techniques can be found in the spreadsheet ('Fish method review table'), associated with NECR 269 (Franco et al. (2020a)), which is available from Natural England on request,

The monitoring pilot to be planned within this project aims at collecting a robust dataset to characterise the entire fish community in SW inshore waters. Therefore, given the limitations mentioned above, and the marked heterogeneity in the environmental and habitat conditions (types of substrata, hydrodynamic energy, etc.) outlined in section 1.1, a suite of methods is needed to fully capture the diversity and distribution of the associated fish assemblages in the region. Individually, the methods need to be suitable for the monitoring of the fish assemblages at the regional scale, practicable for use in the different habitats occurring in the region, and cost effective. Cumulatively, the overall requirement is to use a complementary range of techniques that can characterise (and where possible quantify) the inshore fish communities across the range of habitats occurring in the region.

A stepwise, tiered approach is proposed to identify the most suitable methods for use in the study area. Based on the review undertaken in Franco et al. (2020a), also including the 'Fish method review table', the fish monitoring techniques have been assessed against a set of criteria that are considered key to the development of a fit-for-purpose, standardised and cost-effective regional monitoring programme, namely practicality (tier 1), suitability (tier 2), and cost-effectiveness (tier 3). Each technique has been ranked according to each criterion (see sections below for details on the ranking method) in order to identify the most viable (i.e. higher ranking) techniques for use to monitor inshore fish assemblages in the SW of England.

4. It is important to note that this is a preliminary assessment, based on the opinion and expert judgment of the authors, as informed by the evidence mentioned above. The applicability and detailed costs of the proposed methods will be further evaluated and integrated during the stakeholder consultation and engagement process that will be undertaken to support the production of a costed plan for the delivery of a holistic, integrated monitoring pilot aimed at characterising the inshore fish communities of the SW of England (see Natural England Commissioned Report: NECR 271, (Franco et al., 2020c)).

2.1 Practicality (Tier 1)

Given the overall requirement for the monitoring plan mentioned above, the applicability of the monitoring methods in different habitats is the first condition that allows to assess how the viability may change across the range of habitats occurring in the region.

Habitats have been defined at two levels, as specified below.

2.1.1 Broad habitat type (Substratum x Energy x Depth) (Tier 1a)

Habitat characteristics such as substratum type, hydrodynamic energy and depth may limit the ability of using of a method in a specific habitat, hence to monitor the fish community in that habitat. For example, bottom trawling methods are practicable on sedimentary habitats where there are no obstructions, but they cannot be used on rocky substrata, while underwater visual census diving surveys are constrained by energy conditions and depth (which also affects visibility) (Franco et al., 2020a).

Here, the viability of different methods has been assessed in relation to their applicability in different habitats, as broadly defined by the combination of substratum type, hydrodynamic energy and depth.

Information on these habitat characteristics has been derived for the study area from the correspondent qualifiers of EUNIS habitats as given in the UKSeaMap 2018 (JNCC, 2018). For the purpose of this assessment, sedimentary substrata have been contrasted to rocky or hard substrata, whilst high energy conditions are contrasted with moderate/low energy conditions.

Biozones commonly used in the definition of EUNIS habitats have been used as a proxy for of depth, with relevant biozones occurring the inshore areas of the study region being the littoral, infralittoral and circalittoral zones. It is acknowledged that the depth boundary between infralittoral and circalittoral is defined as a function of light penetration to the seabed (it being 1%, i.e. the minimum amount required for kelp growth), and that the associated bathymetric boundary may therefore vary in relation to water clarity. For the purpose of this assessment, the indicative boundary between the infralittoral and circalittoral zones is considered to be at a depth of between 30 m (e.g. on sedimentary habitats) and 50 m (e.g. on rocky habitats).

Based on the combination of these characteristics, twelve possible broadly-defined habitat types have been identified (Table 2). EUNIS codes for the habitats thus identified are given in Appendix 1 for reference, as obtained from UKSeaMap 2018 (JNCC, 2018), in particular considering the habitats present within the SW inshore areas.

The applicability of the different monitoring techniques in each of these habitats has been assessed using the information on the operational constraints of these methods, as provided in the review in Franco et al. (2020a) and the associated ‘Fish method review table’.

In particular, in each habitat, each method has been ranked using the following scoring (T1a):

- Where there are no operational constraints limiting the use of that method in that habitat, a score of 2 is given;
- Where the method can be generally used in the habitat, but there may be operational constraints for using it respectively in part of the habitat, a score of 1 is given. For example, stow net can be used in infralittoral habitats, but it requires strong one-directional currents, hence its use is restricted to estuaries or confined areas where these conditions occur (see review in Franco et al., 2020a).
- Where operational constraints are associated with depth variability within a habitat, a combined score of 1/2 or 2/1 to indicate that constraints exist particularly in shallower or deeper parts of the habitat, respectively (e.g. seine net can only be used in the

shallower parts of the infralittoral biozone, hence a score 2/1 is allocated for its use in infralittoral habitats to account for this);
- Where there are operational constraints that do not allow to use the method on that habitat, 'N/A' is allocated (e.g. beam trawling cannot be undertaken on rocky/hard substrata).

Table 2. Habitat categorisation according to tier 1a (broad habitat type) and tier 1b (sensitive habitats: K, kelp; SG, seagrass; M, mäerl; BR, biogenic reef; SP, sea-pen and burrowing megafauna communities). P indicates the possible occurrence of a specific sensitive habitat within the conditions defined for each broad habitat type.

Tier 1a - Broad habitat type				**Tier 1b - Sensitive habitat**				
Substratum	**Energy**	**Depth**	**Habitat code**	**K**	**SG**	**M**	**BR**	**SP**
Sediment	low/ moderate	littoral	SLL		P		P	
		infralittoral	SLI		P	P	P	
		circalittoral	SLC				P	P
	high	littoral	SHL				P	
		infralittoral	SHI				P	
		circalittoral	SHC				P	
Rock / hard substratum	low/ moderate	littoral	RLL					
		infralittoral	RLI	P				
		circalittoral	RLC					
	high	littoral	RHL					
		infralittoral	RHI	P				
		circalittoral	RHC					

2.1.1 Sensitive habitats (Tier 1b)

Although a given method can be used for monitoring fish associated to a broadly defined habitat (as per tier 1a), there may be concerns about the use of such a technique where it may be destructive to the habitat, as for example bottom trawls (Elliott and Hemingway, 2002; see Franco et al. (2020a) and the associated 'Fish method review table' where this aspect is assessed for the different monitoring techniques). Such concerns are particularly significant for those areas of the broadly-defined habitat where sensitive habitat features as for example submerged macrophytes or reef-forming species occur, as opposed to open substratum (i.e. where these sensitive habitats do not occur). This may lead to restrictions in the use of certain techniques in these sensitive habitats, which need to be accounted for in the assessment of the fish monitoring method viability.

Protected habitat features occurring in the study region (as outlined in section 1.1) are considered, including specifically kelp, seagrass, maërl, biogenic reef (e.g. honeycomb and ross worm reefs), and sea-pen and burrowing megafauna communities[7]. The occurrence of these sensitivities within the habitats defined in tier 1a (Table 2) depends on the ecological

[7] Sea-pen and burrowing megafauna communities were included for completeness, although it is likely they are less represented in inshore areas, this habitat being mainly associated with stable mud substrata in deeper areas.

preferences of the different structuring organisms. For example, seagrass beds develop in intertidal and shallow subtidal areas on sands and muds that are sheltered from significant wave action; kelp vegetation develops predominantly on rocky reef habitat in the infralittoral zone; mäerl beds are typically found in the infralittoral zone above 20 m depth (UK BAP Priority Habitat descriptions[8]).

The possible impact of fish monitoring methods on these sensitive habitats has been assessed using the information on the environmental implications associated to the use of these methods (e.g. due to their destructive nature), as provided in the review in Franco et al. (2020a) and the associated 'Fish method review table'. Known restrictions (e.g. in fishing methods, based on IFCAs byelaws) has also been taken into consideration.

In particular, in each habitat, each method has been ranked using the following scoring (T1b):

- Where there are no restrictions associated with environmental concerns regarding the use of that method in that sensitive habitat, a score of 2 is given;
- Where, although the method can be technically used, there may be environmental concerns (e.g. destruction of the habitat by trawling on it or by anchoring nets) that may restrict its application in that habitat, a score of 1 is given;
- Where the method is not relevant to the specific sensitive habitat as the latter occurs within a broad habitat type where operational constraints prevent the use of the method (tier 1a), 'N/A' is allocated.

2.2 Suitability (Tier 2)

Although there may be no restrictions (operational or environmental) to the use of a method in a certain habitat, there are intrinsic characteristics of the method (e.g. the scale at which it operates, the type of data it produces) that may influence how suitable it is for the specific purposes of the monitoring in this project.

In particularly, the characteristics outlined below have been considered to be relevant to assessing the viability of methods for characterising inshore fish assemblages in the SW region. The methods have been ranked according to the defined criteria (details below), thus allowing to establish priorities in the selection of more viable (higher ranking) techniques over less viable (lower ranking) ones within the suite of methods that are practicable in each habitat (as per previous tier).

2.2.1 Monitoring scope (Tier 2a)

As mentioned before, there is not a single method that allows to assess the entire fish community of a region, as all methods are selective to some degree. However some techniques are more selective than others, as they are designed to target individual species at given stages of their life (e.g. during migrations) and are used to investigate aspects of the life history of the selected species rather than to characterise the whole fish assemblage (Franco et al., 2020a).

For the purpose of obtaining data characterising the inshore fish assemblages in the SW region, techniques that allow to obtain datasets as representative as possible of the entire inshore fish community should be prioritised over methods that are very specific. Within the latter category, we also include methods that, albeit being designed to assess multiple

[8] http://jncc.defra.gov.uk/PDF/UKBAP_PriorityHabitatDesc-Rev2011.pdf

species at a time, are limited in the ability of determining the identity of the different species assessed.

Each method has been ranked accordingly, using the following scoring (T2a):

- Where the technique provides data pertaining the assemblage of species making up the fish community, a score of 2 is given;
- Where it only provides data pertaining a single species, or where, even where multiple species are assessed, the method alone does not allow to determine their identity, a score of 1 is given.

It is emphasised that the latter type of methods may be useful for specific, targeted assessments of fish populations (use by one selected species of a given area, or passage through confined areas, e.g. fish passes). Therefore, although they may not be viable as core methods for the regional monitoring of inshore fish communities, they may be relevant for more detailed, integration studies.

2.2.2 Spatial coverage (Tier 2b)

The monitoring is to be designed at the regional scale, in the case study area, with potential for being rolled out to other regions. Therefore, suitability of the monitoring methods for use at this broad spatial scale are a criterion for assessing method viability, and techniques that collect sample data representative of a broader spatial area should be prioritised.

The spatial scale represented by the data collected with a method is influenced by the area of influence of the technique. This accounts for the sample unit area and the catchability quotient, and is influenced by the method characteristics (e.g. area swept by a gear, or spatial detection range of observation techniques), and also by the mobility of the species targeted (e.g. diadromous fish), as described in Elliott and Hemingway (2002). These authors distinguished the spatial coverage of different fish monitoring methods into microhabitat (<10 m around the gear/method), mesohabitat (10-100 m), and macrohabitat (>100 m).

Elliott and Hemingway's (2002) spatial criteria are also applied in the method review in Franco et al. (2020a; including the summary matrix 'Fish method review table' provided therein), and they have been used to qualify the method prioritisation in this tier. Specifically, the monitoring method has been ranked as follows (T2b):

- For techniques that collect data representative of the macrohabitat, a score of 3 is given;
- For techniques that work at the mesohabitat scale, a score of 2 is given;
- For techniques that work at the microhabitat scale, a score of 1 is given.

2.3 Cost-effectiveness (Tier 3)

The costs associated with the different methods have not been estimated in detail at this stage, therefore a complete and quantitative assessment of cost-effectiveness is not undertaken here. However, some factors have been identified as likely contributing to how cost-effective a method can be, as they provide an added value to the choice of one method over another, and therefore they may be used as proxies for cost-effectiveness. These are described below.

Similarly to the approach in tier 2, the ranking of the methods according to the criteria defined in this tier are used to further prioritise more viable (higher ranking) techniques over less viable (lower ranking) ones across the suite of methods that are practicable in each habitat (as per tier 1).

2.3.1 Data quality (Tier 3a)

The quality of data provided by one technique is an important element to prioritise the choice of possibly suitable methods that can be applied to monitor fish assemblages in a certain habitat. In particular, where the technique only provides qualitative data (or semi-quantitative at best), the use of that technique alone may not be sufficient to fully (quantitatively) estimate fish assemblages in the study area. Therefore, where this technique is selected, it would need to be complemented by other methods to obtain quantitative information, thus likely increasing the monitoring costs.

The information on the type of data that can be obtained with the different methods and the metrics that can be derived for the assessment of inshore fish communities has been reviewed in Franco et al. (2020a; see in particular the 'Fish method review table'). Based on this, the monitoring methods have been ranked as follows (T3a):

- Methods able to provide quantitative data are scored a 2;
- Techniques that provide only qualitative data (or semi-quantitative at best) are scored a 1.

2.3.2 Existing standardised monitoring plans for the area (Tier 3b)

The prior existence of standardised monitoring plans in the study area is an important factor when considering options for standardising, and optimising the cost-effectiveness of wider monitoring plans for inshore fish communities. This not only ensures comparability of the data being collected with existing and previous monitoring, but also allows to identify equipment and expertise availability for the study area that can lead to cost reductions.

Therefore, the existence of standardised monitoring plans using a specific technique is considered an added value that may help in prioritising one method over another. Information on existing fish monitoring programmes in the study area has been obtained during an initial phase of consultation with stakeholders including government agencies (Natural England, Environment Agency, Marine Management Organisation, Devon and Severn IFCA) and scientific associations and academia (the Marine Biological Association, the University of Hull, the University of Plymouth), as part of this project. However, it is of note that the review of the existing or planned fish monitoring programmes in the region is not part of the scope of this project, and therefore the information obtained so far does not exhaustively represent all the monitoring programmes (past, present or planned for the future) in the study area. Based on this, the monitoring techniques have been assigned a qualitative mark ('Yes' where there is knowledge of an existing monitoring programme using those methods, or with 'N/A' otherwise) to qualify monitoring methods in this tier of assessment (T3b), bearing in mind that further consultation with stakeholders throughout the project and further information that may be obtained outside this project may help in better substantiate this additional value.

2.4 Method viability (overall ranking)

In order to prioritise the different fish monitoring techniques for the purpose of designing a pilot regional monitoring plan for the SW of England, the scores attributed within the tiers mentioned above have been combined into an overall ranking.

For each method (*i*), the overall viability ranking V_i is calculated as follows:

- For broad habitat types with no sensitive habitats, the ranking of the method according to its practicality in broad habitat types (*T1a*) is weighted by the sum of the scores allocated to the method in tiers 2a and 2b (*T2*) and the score allocated in tier 3a (*T3a*):
$$V_i = T1a_i \times T2_i \times T3a_i$$
- For broad habitat types where one of the sensitive habitats (*j*) occurs, the ranking of the method according to its practicality in broad habitat types (*T1a*) has been first weighted by the score allocated to the method use in the specific sensitive habitat as given in tier 1b (*T2b*), before further weighting the resulting score as in the point above:
$$V_{ij} = (T1a_i \times T1b_{ij}) \times T2_i \times T3a_i$$

As a result of the calculations above, the overall ranking V_i may range between 1 and 20 when considering the viability of the methods in broad habitat types with no sensitive habitats, and between 0.5 and 20 when considering the viability of the methods in broad habitat types where one of the sensitive habitats occur, with N/A indicating habitat conditions where the method is not applicable.

As the assessment in tier 3b is not exhaustive, this score has only be considered as an additional qualifier to provide additional value to the method towards cost effectiveness where there is knowledge of existing monitoring programmes using a certain method. As such, this is not included in the calculations above, but can be used as a further discriminant element supporting the selection of one method over another where the choice is between highly viable (higher ranking) techniques.

Similarly, the information on the target organisms has been included as a further qualifier of the methods to aid selection between viable techniques. In particular, the components of the fish assemblage that a method allows to effectively assess are indicated as an additional attribute of the method, in relation to the vertical distribution of the target species (B for benthic species (including flatfish), D for demersal species, P for pelagic species), and the targeted life stages (A for adults, J for juveniles, L for larvae and/or eggs), as derived from the review in Franco et al. (2020a) and summarised in the ‘Fish method review table’.

3. Results and discussion

Using the fish monitoring methods as listed in the 'Fish method review table' (Franco et al., 2020a), and the information given therein, each method has been scored based on its applicability in broad habitat types (tier 1a) and in specific sensitive habitats (tier 1b), with the resulting ranking shown in Table 3.

The ranking of methods according to tier 2a (Table 4) takes into consideration their monitoring scope. Based on this criterion, the following methods are considered less viable for application in a regional monitoring of inshore fish communities:

- *Hydroacoustics and acoustic cameras*, due to their inability to provide a confident assessment of the identity of the species assessed (Horne, 2000; Martignac et al., 2015; and other references in sections 3.2.1 and 3.2.2 in Franco et al., 2020a). As a result, these methods often require to be coupled with other methods (e.g. trawling) that provide groundtruthing of the species detected in the study area.
- *Acoustic telemetry and conventional tagging*, as these monitoring techniques are aimed at assessing one target species at a time (the one that is tagged at the beginning of the procedure) to investigate spatial aspects of their life history as for example migrations, movements, and behaviour, rather than assessing the fish assemblage as a whole. In addition, these methods are not normally used to quantify fish abundance, unless they are used as part of mark–recapture studies (see sections 3.2.3 and 3.3 in Franco et al., 2020a).
- *Targeted PCR (DNA-based) methods*, as they also rely on sequencing DNA from a single organism at a time using species-specific primers, while there are more viable alternative methods (e.g. high-throughput sequencing methods such as e-DNA metabarcoding) that are designed to identify DNA from the whole community (Hänfling et al., 2017; and other references in sections 4.1 in Franco et al., 2020a).

It is emphasised that the methods above may be useful for specific, targeted assessments of fish populations (use by one selected species of a given area, or passage through confined areas, e.g. fish passes), and therefore they may be relevant for more detailed, integration studies compared to the assessment with a broader scale and scope that is the one of fish communities in regional inshore waters.

The ranking of methods according to tier 2b (Table 4) addresses the spatial scale represented by the data collected with a method, in relation to the requirements for designing a fish monitoring plan at the regional scale. Specifically, techniques that collect data representative of the larger (macrohabitat) scale (e.g. trawls, diving surveys) are prioritised over methods such as for example drop and bottle traps, which operate at a smaller (microhabitat) scale and therefore are considered less suitable for monitoring fish assemblages at the regional scale. Methods that work at the mesoscale at best (e.g. baited video monitoring) have an intermediate score, and they should be considered for possible use in the monitoring plan where no alternative methods operating at the macroscale are available to sample fish assemblages in a given habitat of interest (e.g. fyke nets in intertidal areas).

Additional ranking of monitoring methods according to data quality (tier 3a) is also shown in Table 4, along with the indication of methods for which there is knowledge of standardised monitoring programmes in the study area (tier 3b).

Table 3. Ranking of fish monitoring methods according to scoring criteria for method applicability in broad habitat types (tier 1a; score 1-2) and in specific sensitive habitats (tier 1b, score 0.5-1). For details of scoring criteria see sections 2.1.1 and 2.1.2 of the report. Codes for broad habitat types and sensitive habitats are as in Table 2. Note: blank cells denote technique 'not applicable'.

Method Type	Technique	Tier 1 - Practicality																
		T1a) Broad habitat type												T1b) Sensitive habitat				
		SLL	**SLI**	**SLC**	**SHL**	**SHI**	**SHC**	**RLL**	**RLI**	**RLC**	**RHL**	**RHI**	**RHC**	**K**	**SG**	**M**	**BR**	**SP**
Trawl nets	Beam trawl		2	2		2	2								0.5	0.5	0.5	0.5
	Otter trawl (demersal)		1/2	2		1/2	2		2	2		2	2		0.5	0.5	0.5	0.5
	Otter trawl (pelagic)		1/2	2		1/2	2		2	2		2	2	1(*)	1	1	1	1
	Pelagic trawl		1/2	2		1/2	2		2	2		2	2	1(*)	1	1	1	1
	Agassiz trawl		1/2	2		1/2	2								0.5	0.5	0.5	0.5
	Isaacs–Kid midwater trawl		2			2			2			2		1(*)	1	1	1	1
	RMT-8 (trawl)		2			2			2			2		1(*)	1	1	1	1
Encircling nets	Beach seine		2/1			2/1									0.5	0.5	0.5	
Fixed nets and traps	Fyke net	2	2/1		1										0.5	0.5	0.5	
	Fixed net/trap	2	2/1		1										0.5	0.5	0.5	
	Stow net		1			1			1			1		1	1	1	1	
	Gillnet / trammel net		2	2/1					2	2/1					0.5	0.5	0.5	0.5
	Block/stop net	2																
	Drop net		2/1												0.5	0.5	0.5	
	Drop trap		2/1												0.5	0.5	0.5	
	Popnet & pull-up traps		2/1												0.5	0.5	0.5	
	Pitfall (bottle) trap	2	2/1		1			2	2/1					1	1	1	1	
Lines	Longline		2	2/1		2	2/1		2	2/1		2	2/1		0.5	0.5	0.5	0.5
	Handline		2	2/1		2	2/1		2	2/1		2	2/1		1	1	1	1
Plankton samplers	Plankton net		2	2/1		2	2/1		2	2/1		2	2/1	1(*)	1	1	1	1
	Bongo net		2	2		2	2		2	2		2	2	1(*)	1	1	1	1
	Gulf sampler		1/2	2		1/2	2		1/2	2		1/2	2	1(*)	1	1	1	1
Power station	Power station screens		2	2		2	2		2	2		2	2					

(*) pelagic trawls and samplers can be used above the kelp canopy, where possible

Table continued…

Method Type	Technique	Tier 1 - Practicality																
		T1a) Broad habitat type												T1b) Sensitive habitat				
		SLL	**SLI**	**SLC**	**SHL**	**SHI**	**SHC**	**RLL**	**RLI**	**RLC**	**RHL**	**RHI**	**RHC**	**K**	**SG**	**M**	**BR**	**SP**
Hand-gathering methods	Elver dip net		2/1			2/1												
	Push net / Kick sampling		2/1			2/1									0.5	0.5	0.5	
Visual observation	Diving		2						2					1	1	1	1	
	Baited underwater video		2	2					2	2				1	1	1	1	1
Acoustic detection	Hydroacoustics		2	2		2	2		2	2		2	2			1	1	1
	Acoustic cameras		2	2/1		2	2/1		2	2/1		2	2/1			1	1	1
	Acoustic telemetry		2	2		2	2		2	2		2	2	1	1	1	1	1
Direct DNA	PCR	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
	qPCR	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
	ddPCR	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
eDNA	Metabarcoding	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
	PCR-free analysis	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1

Table 4. Ranking of fish monitoring methods according to scoring criteria for method suitability based on monitoring scope (tier 2a, score 1-2) and spatial coverage (tier 2b, score 1-3), and for cost-effectiveness based on data quality (tier 3a, score 1-2) and existence of standardised monitoring programmes for the study region (tier 3b, qualitative). For details of scoring criteria see sections 2.2 and 2.3 of the report.

Method Type	**Technique**	**Tier 2 - Suitability**		**Tier 3 - Cost effectiveness**	
		T2a) Scope	**T2b) Spatial scale**	**T3a) Data quality**	**T3b) Existing monitoring**
Trawl nets	Beam trawl	2	3	2	Yes
	Otter trawl (demersal)	2	3	2	Yes
	Otter trawl (pelagic)	2	3	2	N/A
	Pelagic trawl	2	3	2	N/A
	Agassiz trawl	2	3	2	N/A
	Isaacs–Kid midwater trawl	2	3	2	N/A
	RMT-8 (trawl)	2	3	2	N/A
Encircling nets	Beach seine	2	2	2	Yes
Fixed nets and traps	Fyke net	2	2	2	Yes
	Fixed net/trap	2	3	1	N/A
	Stow net	2	3	2	N/A
	Gillnet / trammel net	2	3	2	N/A
	Block/stop net	2	1	1	N/A
	Drop net	2	2	2	N/A
	Drop trap	2	1	2	N/A
	Popnet & pull-up traps	2	2	2	N/A
	Pitfall (bottle) trap	2	1	1	N/A
Lines	Longline	2	2	1	N/A
	Handline	2	2	1	N/A
Plankton samplers	Plankton net	2	3	2	N/A
	Bongo net	2	3	2	N/A
	Gulf sampler	2	3	2	N/A
Power station	Power station screens	2	3	2	N/A
Hand-gathering methods	Elver dip net	1	1	2	N/A
	Push net / Kick sampling	2	1	2	Yes
Visual observation	Diving	2	3	2	N/A
	Baited underwater video	2	2	2	N/A
Acoustic detection	Hydroacoustics	1	3	2	N/A
	Acoustic cameras	1	3	2	N/A
	Acoustic telemetry	1	3	2	Yes
Direct DNA	PCR	1	3	1	N/A
	qPCR	1	3	1	N/A
	ddPCR	1	3	1	N/A
eDNA	Metabarcoding	2	3	1	N/A
	PCR-free analysis	2	3	1	N/A

The overall viability ranking of the different methods as resulting from combining the scores assigned in the different tiers of the assessment is given in Table 5 for broad habitat types with no sensitive habitats and Tables 6-10 for broad habitat types including each of the sensitive habitats considered in this assessment.

Table 5. Overall viability ranking of monitoring methods for use in broad habitat types with no sensitive habitats (score range 3 to 20). Information on the existence of standardised monitoring programmes for the study region (tier 3b) and on the target components of the fish assemblage (species vertical distribution: B for benthic species (including flatfish), D for demersal species, P for pelagic species; and life stages: A for adults, J for juveniles, L for larvae and/or eggs) are also shown as additional qualifiers of the method. Codes for broad habitat types and sensitive habitats are as in Table 2. Note: blank cells denote technique 'not applicable'.

Method Type	**Technique**	**Overall viability ranking for broad habitat type with no sensitive habitat**												**T3b) Existing monitoring**	**Benthic/ Demersal/ Pelagic**	**Adult/ Juvenile/ Larvae**
		SLL	**SLI**	**SLC**	**SHL**	**SHI**	**SHC**	**RLL**	**RLI**	**RLC**	**RHL**	**RHI**	**RHC**			
Trawl nets	Beam trawl		20	20		20	20							Yes	B, D	A, J
	Otter trawl (demersal)		10/20	20		10/20	20		20	20		20	20	Yes	B, D	A, J
	Otter trawl (pelagic)		10/20	20		10/20	20		20	20		20	20		D, P	A, J
	Pelagic trawl		10/20	20		10/20	20		20	20		20	20		P	A, J, L
	Agassiz trawl		10/20	20		10/20	20								B, D	A, J
	Isaacs–Kid midwater trawl		20			20			20			20			P	J, L
	RMT-8 (trawl)		20			20			20			20			P	J, L
Encircling nets	Beach seine		16/8			16/8								Yes	B, D, P	A, J
Fixed nets and traps	Fyke net	16	16/8		8									Yes	B, D	A, J
	Fixed net/trap	10	10/5		5										B, D	A, J
	Stow net		10			10			10			10			B, D, P	A, J
	Gillnet / trammel net		20	20/10					20	20/10					(B), D, P	A, (J)
	Block/stop net	6													B, D	A, J
	Drop net		16/8												B, D, P	A, J

Table continued…

Method Type	Technique	Overall viability ranking for broad habitat type with no sensitive habitat												T3b) Existing monitoring	Benthic/ Demersal/ Pelagic	Adult/ Juvenile/ Larvae
		SLL	SLI	SLC	SHL	SHI	SHC	RLL	RLI	RLC	RHL	RHI	RHC			
Fixed nets and traps	Drop trap		12/6												B, D	J, L
	Popnet & pull-up traps		16/8												B, D	A, J, L
	Pitfall (bottle) trap	6	6/3		3			6	6/3						B, D	J, L
Lines	Longline		8	8/4		8	8/4		8	8/4		8	8/4		D, P	A
	Handline		8	8/4		8	8/4		8	8/4		8	8/4		D, P	A
Plankton samplers	Plankton net		20	20/10		20	20/10		20	20/10		20	20/10		P	L
	Bongo net		20	20		20	20		20	20		20	20		P	J, L
	Gulf sampler		10/20	20		10/20	20		10/20	20		10/20	20		P	J, L
Power station	Power station screens		20	20		20	20		20	20		20	20		B, D, P	A, J
Hand-gathering methods	Elver dip net		8/4			8/4									D, P	J, L
	Push net / Kick sampling		12/6			12/6								Yes	B, D	A, J, L
Visual observati on	Diving		20						20						B, D, P	A, J
	Baited underwater video		16	16					16	16					(B), D, (P)	A, (J)
Acoustic detection	Hydroacous tics		16	16		16	16		16	16		16	16		D, P	A, J
	Acoustic cameras		16	16/8		16	16/8		16	16/8		16	16/8		B, D, P	A, J
	Acoustic telemetry		16	16		16	16		16	16		16	16	Yes	B, D, P	A, J

Table continued…

Method Type	Technique	Overall viability ranking for broad habitat type with no sensitive habitat												T3b) Existing monitoring	Benthic/ Demersal/ Pelagic	Adult/ Juvenile/ Larvae
		SLL	SLI	SLC	SHL	SHI	SHC	RLL	RLI	RLC	RHL	RHI	RHC			
Direct DNA	PCR	8	8	8	8	8	8	8	8	8	8	8	8	N/A	B, D, P	N/A
	qPCR	8	8	8	8	8	8	8	8	8	8	8	8	N/A	B, D, P	N/A
	ddPCR	8	8	8	8	8	8	8	8	8	8	8	8	N/A	B, D, P	N/A
eDNA	Metabarcoding	10	10	10	10	10	10	10	10	10	10	10	10	N/A	B, D, P	N/A
	PCR-free analysis	10	10	10	10	10	10	10	10	10	10	10	10	N/A	B, D, P	N/A

Table 6. Overall viability ranking of monitoring methods for use in broad habitat types with Kelp (score range 0.5 to 20). Only broad habitat types where kelp is likely to occur (see Table 2) are shown. Information on the existence of standardised monitoring programmes for the study region (tier 3b) and on the target components of the fish assemblage (species vertical distribution: B for benthic species (including flatfish), D for demersal species, P for pelagic species; and life stages: A for adults, J for juveniles, L for larvae and/or eggs) are also shown as additional qualifiers of the method. Codes for broad habitat types and sensitive habitats are as in Table 2. Note: blank cells denote technique 'not applicable'.

Method Type	Technique	Overall viability ranking for broad habitat type with Kelp		T3b) Existing monitoring	Benthic/ Demersal/ Pelagic	Adult/ Juvenile/ Larvae
		RLI	RHI			
Trawl nets	Beam trawl			Yes	B, D	A, J
	Otter trawl (demersal)			Yes	B, D	A, J
	Otter trawl (pelagic)	20	20		D, P	A, J
	Pelagic trawl	20	20		P	A, J, L
	Agassiz trawl				B, D	A, J
	Isaacs–Kid midwater trawl	20	20		P	J, L
	RMT-8 (trawl)	20	20		P	J, L
Encircling nets	Beach seine			Yes	B, D, P	A, J
Fixed nets and traps	Fyke net			Yes	B, D	A, J
	Fixed net/trap				B, D	A, J
	Stow net	10	10		B, D, P	A, J
	Gillnet / trammel net				(B), D, P	A, (J)
	Block/stop net				B, D	A, J
	Drop net				B, D, P	A, J
	Drop trap				B, D	J, L
	Popnet & pull-up traps				B, D	A, J, L
	Pitfall (bottle) trap	6/3			B, D	J, L
Lines	Longline				D, P	A
	Handline				D, P	A
Plankton samplers	Plankton net	20	20		P	L
	Bongo net	20	20		P	J, L
	Gulf sampler	10/20	10/20		P	J, L
Power station	Power station screens				B, D, P	A, J

Table continued…

Method Type	Technique	Overall viability ranking for broad habitat type with Kelp		T3b) Existing monitoring	Benthic/ Demersal/ Pelagic	Adult/ Juvenile/ Larvae
		RLI	RHI			
Hand-gathering methods	Elver dip net				D, P	J, L
	Push net / Kick sampling			Yes	B, D	A, J, L
Visual observation	Diving	20			B, D, P	A, J
	Baited underwater video	16			(B), D, (P)	A, (J)
Acoustic detection	Hydroacoustics				D, P	A, J
	Acoustic cameras				B, D, P	A, J
	Acoustic telemetry	16	16	Yes	B, D, P	A, J
Direct DNA	PCR	8	8		B, D, P	
	qPCR	8	8		B, D, P	
	ddPCR	8	8		B, D, P	
eDNA	Metabarcoding	10	10		B, D, P	
	PCR-free analysis	10	10		B, D, P	

Table 7. Overall viability ranking of monitoring methods for use in broad habitat types with Seagrass (score range 0.5 to 20). Only broad habitat types where seagrass is likely to occur (see Table 2) are shown. Information on the existence of standardised monitoring programmes for the study region (tier 3b) and on the target components of the fish assemblage (species vertical distribution: B for benthic species (including flatfish), D for demersal species, P for pelagic species; and life stages: A for adults, J for juveniles, L for larvae and/or eggs) are also shown as additional qualifiers of the method. Codes for broad habitat types and sensitive habitats are as in Table 2. Note: blank cells denote technique 'not applicable'.

Method Type	**Technique**	**Overall viability ranking for broad habitat type with Seagrass**		**3b) Existing monitoring**	**Benthic/ Demersal/ Pelagic**	**Adult/ Juvenile/ Larvae**
		SLL	**SLI**			
Trawl nets	Beam trawl		10	Yes	B, D	A, J
	Otter trawl (demersal)		5/10	Yes	B, D	A, J
	Otter trawl (pelagic)		10/20		D, P	A, J
	Pelagic trawl		10/20		P	A, J, L
	Agassiz trawl		5/10		B, D	A, J
	Isaacs–Kid midwater trawl		20		P	J, L
	RMT-8 (trawl)		20		P	J, L
Encircling nets	Beach seine		8/4	Yes	B, D, P	A, J
Fixed nets and traps	Fyke net	8	8/4	Yes	B, D	A, J
	Fixed net/trap	5	5/2.5		B, D	A, J
	Stow net		10		B, D, P	A, J
	Gillnet / trammel net		10		(B), D, P	A, (J)
	Block/stop net				B, D	A, J
	Drop net		8/4		B, D, P	A, J
	Drop trap		6/3		B, D	J, L
	Popnet & pull-up traps		8/4		B, D	A, J, L
	Pitfall (bottle) trap	6	6/3		B, D	J, L
Lines	Longline		4		D, P	A
	Handline		8		D, P	A
Plankton samplers	Plankton net		20		P	L
	Bongo net		20		P	J, L
	Gulf sampler		10/20		P	J, L
Power station	Power station screens				B, D, P	A, J

Table continued…

Method Type	Technique	Overall viability ranking for broad habitat type with Seagrass		3b) Existing monitoring	Benthic/ Demersal/ Pelagic	Adult/ Juvenile/ Larvae
		SLL	SLI			
Hand-gathering methods	Elver dip net				D, P	J, L
	Push net / Kick sampling		6/3	Yes	B, D	A, J, L
Visual observation	Diving		20		B, D, P	A, J
	Baited underwater video		16		(B), D, (P)	A, (J)
Acoustic detection	Hydroacoustics				D, P	A, J
	Acoustic cameras				B, D, P	A, J
	Acoustic telemetry		16	Yes	B, D, P	A, J
Direct DNA	PCR	8	8		B, D, P	
	qPCR	8	8		B, D, P	
	ddPCR	8	8		B, D, P	
eDNA	Metabarcoding	10	10		B, D, P	
	PCR-free analysis	10	10		B, D, P	

Table 8. Overall viability ranking of monitoring methods for use in broad habitat types including Mäerl beds (score range 0.5 to 20). Only broad habitat types where mäerl beds are likely to occur (see Table 2) are shown. Information on the existence of standardised monitoring programmes for the study region (tier 3b) and on the target components of the fish assemblage (species vertical distribution: B for benthic species (including flatfish), D for demersal species, P for pelagic species; and life stages: A for adults, J for juveniles, L for larvae and/or eggs) are also shown as additional qualifiers of the method. Codes for broad habitat types and sensitive habitats are as in Table 2. Note: blank cells denote technique 'not applicable'.

Method Type	**Technique**	**Overall viability ranking for broad habitat type with Mäerl**	**3b) Existing monitoring**	**Benthic/ Demersal/ Pelagic**	**Adult/ Juvenile/ Larvae**
		SLI			
Trawl nets	Beam trawl	10	Yes	B, D	A, J
	Otter trawl (demersal)	5/10	Yes	B, D	A, J
	Otter trawl (pelagic)	10/20		D, P	A, J
	Pelagic trawl	10/20		P	A, J, L
	Agassiz trawl	5/10		B, D	A, J
	Isaacs–Kid midwater trawl	20		P	J, L
	RMT-8 (trawl)	20		P	J, L
Encircling nets	Beach seine	8/4	Yes	B, D, P	A, J
Fixed nets and traps	Fyke net	8/4	Yes	B, D	A, J
	Fixed net/trap	5/2.5		B, D	A, J
	Stow net	10		B, D, P	A, J
	Gillnet / trammel net	10		(B), D, P	A, (J)
	Block/stop net			B, D	A, J
	Drop net	8/4		B, D, P	A, J
	Drop trap	6/3		B, D	J, L
	Popnet & pull-up traps	8/4		B, D	A, J, L
	Pitfall (bottle) trap	6/3		B, D	J, L
Lines	Longline	4		D, P	A
	Handline	8		D, P	A
Plankton samplers	Plankton net	20		P	L
	Bongo net	20		P	J, L
	Gulf sampler	10/20		P	J, L
Power station	Power station screens			B, D, P	A, J

Table continued…

Method Type	Technique	Overall viability ranking for broad habitat type with Mäerl	3b) Existing monitoring	Benthic/ Demersal/ Pelagic	Adult/ Juvenile/ Larvae
		SLI			
Hand-gathering methods	Elver dip net			D, P	J, L
	Push net / Kick sampling	6/3	Yes	B, D	A, J, L
Visual observation	Diving	20		B, D, P	A, J
	Baited underwater video	16		(B), D, (P)	A, (J)
Acoustic detection	Hydroacoustics	16		D, P	A, J
	Acoustic cameras	16		B, D, P	A, J
	Acoustic telemetry	16	Yes	B, D, P	A, J
Direct DNA	PCR	8		B, D, P	
	qPCR	8		B, D, P	
	ddPCR	8		B, D, P	
eDNA	Metabarcoding	10		B, D, P	
	PCR-free analysis	10		B, D, P	

Table 9. Overall viability ranking of monitoring methods for use in broad habitat types including Biogenic reefs (score range 0.5 to 20). Only broad habitat types where biogenic reefs are likely to occur (see Table 2) are shown. Information on the existence of standardised monitoring programmes for the study region (tier 3b) and on the target components of the fish assemblage (species vertical distribution : B for benthic species (including flatfish), D for demersal species, P for pelagic species; and life stages: A for adults, J for juveniles, L for larvae and/or eggs) are also shown as additional qualifiers of the method. Codes for broad habitat types and sensitive habitats are as in Table 2. Note: blank cells denote technique 'not applicable'.

Method Type	**Technique**	**Overall viability ranking for broad habitat type with Biogenic reef**						**T3b) Existing monitoring**	**Benthic/ Demersal/ Pelagic**	**Adult/ Juvenile/ Larvae**
		SLL	**SLI**	**SLC**	**SHL**	**SHI**	**SHC**			
Trawl nets	Beam trawl		10	10		10	10	Yes	B, D	A, J
	Otter trawl (demersal)		5/10	10		5/10	10	Yes	B, D	A, J
	Otter trawl (pelagic)		10/20	20		10/20	20		D, P	A, J
	Pelagic trawl		10/20	20		10/20	20		P	A, J, L
	Agassiz trawl		5/10	10		5/10	10		B, D	A, J
	Isaacs–Kid midwater trawl		20			20			P	J, L
	RMT-8 (trawl)		20			20			P	J, L
Encircling nets	Beach seine		8/4			8/4		Yes	B, D, P	A, J
Fixed nets and traps	Fyke net	8	8/4		4			Yes	B, D	A, J
	Fixed net/trap	5	5/2.5		2.5				B, D	A, J
	Stow net		10			10			B, D, P	A, J
	Gillnet / trammel net		10	10/5					(B), D, P	A, (J)
	Block/stop net								B, D	A, J
	Drop net		8/4						B, D, P	A, J
	Drop trap		6/3						B, D	J, L
	Popnet & pull-up traps		8/4						B, D	A, J, L
	Pitfall (bottle) trap	6	6/3		3				B, D	J, L
Lines	Longline		4	4/2		4	4/2		D, P	A
	Handline		8	8/4		8	8/4		D, P	A
Plankton samplers	Plankton net		20	20/10		20	20/10		P	L
	Bongo net		20	20		20	20		P	J, L
	Gulf sampler		10/20	20		10/20	20		P	J, L
Power station	Power station screens								B, D, P	A, J

Table continued…

Method Type	**Technique**	**Overall viability ranking for broad habitat type with Biogenic reef**						**T3b) Existing monitoring**	**Benthic/ Demersal/ Pelagic**	**Adult/ Juvenile/ Larvae**
		SLL	**SLI**	**SLC**	**SHL**	**SHI**	**SHC**			
Hand-gathering methods	Elver dip net								D, P	J, L
	Push net / Kick sampling		6/3			6/3		Yes	B, D	A, J, L
Visual observation	Diving		20						B, D, P	A, J
	Baited underwater video		16	16					(B), D, (P)	A, (J)
Acoustic detection	Hydroacoustics		16	16		16	16		D, P	A, J
	Acoustic cameras		16	16/8		16	16/8		B, D, P	A, J
	Acoustic telemetry		16	16		16	16	Yes	B, D, P	A, J
Direct DNA	PCR	8	8	8	8	8	8		B, D, P	
	qPCR	8	8	8	8	8	8		B, D, P	
	ddPCR	8	8	8	8	8	8		B, D, P	
eDNA	Metabarcoding	10	10	10	10	10	10		B, D, P	
	PCR-free analysis	10	10	10	10	10	10		B, D, P	

Table 10. Overall viability ranking of monitoring methods for use in broad habitat types including Sea-pen and burrowing megafauna communities (score range 0.5 to 20). Only broad habitat types where sea-pen and burrowing megafauna communities are likely to occur (see Table 2) are shown. Information on the existence of standardised monitoring programmes for the study region (tier 3b) and on the target components of the fish assemblage (species vertical distribution: B for benthic species (including flatfish), D for demersal species, P for pelagic species; and life stages: A for adults, J for juveniles, L for larvae and/or eggs) are also shown as additional qualifiers of the method. Codes for broad habitat types and sensitive habitats are as in Table 2. Note: blank cells denote technique 'not applicable'.

Method Type	**Technique**	**Overall viability ranking for broad habitat type with Sea-pen and burrowing megafauna communities**	**T3b) Existing monitoring**	**Benthic/ Demersal/ Pelagic**	**Adult/ Juvenile/ Larvae**
		SLC			
Trawl nets	Beam trawl	10	Yes	B, D	A, J
	Otter trawl (demersal)	10	Yes	B, D	A, J
	Otter trawl (pelagic)	20		D, P	A, J
	Pelagic trawl	20		P	A, J, L
	Agassiz trawl	10		B, D	A, J
	Isaacs–Kid midwater trawl			P	J, L
	RMT-8 (trawl)			P	J, L
Encircling nets	Beach seine		Yes	B, D, P	A, J
Fixed nets and traps	Fyke net		Yes	B, D	A, J
	Fixed net/trap			B, D	A, J
	Stow net			B, D, P	A, J
	Gillnet / trammel net	10/5		(B), D, P	A, (J)
	Block/stop net			B, D	A, J
	Drop net			B, D, P	A, J
	Drop trap			B, D	J, L
	Popnet & pull-up traps			B, D	A, J, L
	Pitfall (bottle) trap			B, D	J, L
Lines	Longline	4/2		D, P	A
	Handline	8/4		D, P	A
Plankton samplers	Plankton net	20/10		P	L
	Bongo net	20		P	J, L
	Gulf sampler	20		P	J, L

Table continued…

Method Type	**Technique**	**Overall viability ranking for broad habitat type with Sea-pen and burrowing megafauna communities**	**T3b) Existing monitoring**	**Benthic/ Demersal/ Pelagic**	**Adult/ Juvenile/ Larvae**
		SLC			
Power station	Power station screens	20		B, D, P	A, J
Hand-gathering methods	Elver dip net			D, P	J, L
	Push net / Kick sampling		Yes	B, D	A, J, L
Visual observation	Diving			B, D, P	A, J
	Baited underwater video	16		(B), D, (P)	A, (J)
Acoustic detection	Hydroacoustics	16		D, P	A, J
	Acoustic cameras	16/8		B, D, P	A, J
	Acoustic telemetry	16	Yes	B, D, P	A, J
Direct DNA	PCR	8		B, D, P	
	qPCR	8		B, D, P	
	ddPCR	8		B, D, P	
eDNA	Metabarcoding	10		B, D, P	
	PCR-free analysis	10	N/A	B, D, P	N/A

The overall assessment in the tables above provides a means to prioritise the different methods according to their viability for use in each of different broad habitat types, either in the absence or presence of specific sensitive habitats. It is apparent that no single method is able to efficiently assess all of the components of a fish assemblage. The information on the likely broad community components that can be effectively sampled by each method allows the user to consider combinations of methods to provide an integrated, and exhaustive, monitoring capacity that is able to provide a representative characterisation of the overall fish assemblage.

Possible additional information on the importance of certain areas for specific species or life stages may be required *a priori* to identify the components of main interest. For example, Ellis et al. (2012) indicate the occurrence of high-intensity spawning grounds in inshore areas of north Cornwall and adjacent Celtic Sea for cod and whiting (larvae), sandeels (eggs), sole, plaice, horse mackerel (eggs and larvae); consequently the specific monitoring of early life stages (eggs and larvae) using appropriate methods may also be required to fully characterise the functionality of this area to fish.

It is important to be aware of instances where a given technique provides only qualitative data (or semi-quantitative at best) (see tier 3a in Table 4), as the use of that technique alone may not be sufficient to fully (quantitatively) estimate fish assemblages in the study area; where such methods are selected, consideration should be given to undertaking additional complementary surveys using other methods in order to obtain quantitative information.

Starting from the preliminary assessment of the practicality of the different methods in different habitats (tier 1a and 1b in Table 2), the final viability assessment (Table 5 to Table 10) also considers the sample scale in relation to the study area to be assessed (tier 2b in Table 4). For example, underwater baited video techniques can be theoretically used on any subtidal habitat, provided there is sufficient water clarity for visual detection of fish around the camera system. The use of such technique is considered cost effective for monitoring fish fauna associated with discrete habitat patches as for example rocky reef or kelp forest, also considering that other techniques (e.g. beam trawling) are not suitable for use in these habitats. The approximate cost of a 3-day baited video survey of a relatively small habitat patch (e.g. max 10 km^2) could be as low as £15,000[9], including up to 20 camera deployments (of 60-90 minute each), and all associated costs (vessel, fieldwork, data processing and analysis). However, the monitoring of the inshore fish assemblages at a broader scale, e.g. on sedimentary habitats along a stretch of coast of approx. 80 km, would require a notable increase in the number of stations to be surveyed with baited video cameras, considering the small sampling unit size (micro to mesoscale) compared to the scale of the study area (and of the fish fauna distribution in a broad scale, relatively homogeneous habitat), with associated cost implications. In turn, scientific beam trawling in such an area would be more practical and cost-effective (Table 5), allowing to keep survey costs around £15,000[10] (for a 3-day survey covering 21 stations, distributed according to a stratified sampling design, e.g. 3 depth strata x 7 positions at distance intervals of 10-12 km along the coast). Considerations like this constitute one of the next steps in the identification

[9] This is an approximate estimate, assuming use of a relatively small (12 m long) work boat, vessel and staff mobilisation from the local area and availability of the video camera equipment to the survey team.
[10] This is an approximate estimate, assuming the use of a 2 m scientific beam trawl towed for 500 m at each station, from a small (13 m long) inshore local vessel, with also staff mobilisation from the local area and availability of the survey equipment to the survey team.

of the monitoring design as informed by the spatial heterogeneity and distribution of the sampling conditions in the study SW inshore waters.

In the context of considering existing monitoring programmes for the study area (and possibly also in adjacent regions, to ensure continuity and consistence) (tier 3b in Table 3 to Table 10), these are being identified from discussions with stakeholders. For example, it is acknowledged that Defra has commissioned Cefas with the monitoring of inshore fish on the south coast of England, which involves mainly the beach seine netting (Jim Ellis - Cefas, pers. comm.) We are also aware of a large tagging project being conducted by Plymouth University for the Devon and Severn IFCA, aimed at understanding how European bass (*Dicentrarchus labrax*) move and use estuaries, and which involved implanting acoustic transmitter tags within 150 fish across 3 estuaries (Thomas Stamp – Plymouth University, pers. comm.) Information of additional fish monitoring activities is being collated, as this may inform on the availability of monitoring expertise and equipment and on the possibility of integration with the proposed regional fish monitoring plan in SW inshore waters.

In this context, the monitoring of fish fauna in English transitional waters, as managed and coordinated nationally by the Environment Agency (EA) to comply with the requirements of the Water Framework Directive (WFD), must be considered. Such WFD monitoring of transitional waters has been designed and developed with the aim of supporting the integrated assessment of fish communities in English estuaries, while accounting for the diversity of species and habitats in these environments. The multi-gear approach that has been designed with this purpose can be considered a viable option for the monitoring of inshore fish communities in these environments. It combines the use of trawling (beam and otter trawls), seining, and fyke netting, with the standardisation of nets and sampling operation protocols as defined by the EA (EA, 2011a, 2011b, 2013a, 2013b).

It is therefore suggested that the regional monitoring of fish communities in estuaries reflects this standardised approach, facilitating the collection of data that can be integrated into this national monitoring programme, and that are comparable with existing data (available in the National Fish Populations Database (NFPD): TraC Fish Counts for all Species for all Estuaries and all years[11]). Such monitoring is based on a well-established approach (in formal use since the early 2000s, but often applied before then), and its adoption here is likely to impact positively on the regional monitoring pilot planning in terms of the (local) availability of relevant equipment and expertise, and consequently of costs.

With particular consideration of the study area, several estuaries are present in the SW region, the largest (>50,000 ha) being the Severn, which is the largest coastal plain estuary in the UK. Transitional water bodies of smaller size (mostly 1,000 to 6,500 ha) include the Tamar, Fal and Helford, and Carrick Roads estuaries on the south coast of Cornwall, and the Camel, Taw-Torridge and Parrett estuaries on the north coast of Cornwall and Devon. Several of these estuaries have been consistently surveyed in the last decade (or longer, e.g. Severn), as indicated by data held in the NFPD.

Given the above considerations, it is suggested that the multi-gear method used for WFD assessment purposes is included as the baseline method for estuaries in the study area. Based on the existing survey effort in the estuaries within the SW region, we have estimated a cost of approximately £30,000 per estuary per year (including two seasonal surveys) to undertake multi-gear fish monitoring according to the specifications and protocols provided by the EA for WFD compliance monitoring, with a total estimate of approximately £200,000

[11] https://data.gov.uk/dataset/41308817-191b-459d-aa39-788f74c76623/trac-fish-counts-for-all-species-for-all-estuaries-and-all-years

in the estuaries mentioned above. Additional methods can be used to complement this basic monitoring of estuaries where appropriate (e.g. in rocky habitats, where significant components of the fish assemblage are likely not to be sampled efficiently by standard WFD methods) (see Table 5 to Table 10).

References

BERR, 2008. Atlas of UK Marine Renewable Energy Resources. Atlas Pages. A Strategic Environmental Assessment Report produced by ABPmer, The Met Office and Proudman Oceanographic Laboratory, March 2008.

Defra (2010). *Charting Progress 2. Feeder Report: Healthy and Biologically Diverse Seas*. Available at: http://chartingprogress.defra.gov.uk/ocean-processes-feeder-report

Elliott, M. and Hemingway, K.L. (Eds.) (2002). Fishes in Estuaries. Blackwell Science.

Ellis, J. R., Milligan, S. P., Readdy, L., Taylor, N. and Brown, M. J. (2012). Spawning and nursery grounds of selected fish species in UK waters. Sci. Ser. Tech. Rep., Cefas Lowestoft, 147, Lowestoft.

Environment Agency (2011a). Seine netting for monitoring fish. Operational instruction 145_07. Issued 23/03/2011.

Environment Agency (2011b). Data requirements for WFD transitional fish surveillance monitoring. Operational instruction 328_07. Issued 22/12/2011.

Environment Agency (2013a). Trawling for fish (otter, beam and oyster dredge). Operational instruction 011_07. Issued 30/07/2013.

Environment Agency (2013b). Fyke netting for monitoring fish. Operational instruction 25_07. Issued 06/08/2013.

Franco, A., Nunn, A., Smyth, K., Hänfling, B. and Mazik, K. (2020a). Monitoring methods for assessing inshore fish communities. Natural England Commissioned Reports, NECR 269. ISBN 978-1-78354-594-0

Franco, A., Hänfling, B., Young, M. and Elliott, M. (2020c). Regional monitoring plan for inshore fish communities in the Southwest of England. Natural England Commissioned Reports, NECR 271. ISBN 978-1-78354-596-4

Horne, J. K. (2000). Acoustic approaches to remote species identification: a review. Fisheries Oceanography 9, 356–371.

Martignac, F., Daroux, A., Baglinière, J. L., Ombredane, D. and Guillard, J. (2015). The use of acoustic cameras in shallow waters: new hydroacoustic tools for monitoring migratory fish population. A review of DIDSON technology. Fish and Fisheries 16, 486–510.

JNCC (2018). UKSeaMap 2018 - a broad-scale seabed habitat map for the UK. http://jncc.defra.gov.uk/ukseamap

OSPAR (2010). Background Document for Maërl beds. Biodiversity Series. OSPAR Commission, London. ISBN: 978-1-907390-32-6

Appendix 1. Habitat types (Tier 1a)

Broadly defined habitat types (Tier 3) and correspondent EUNIS habitat codes

Substratum	Energy	Depth	Tier 1a Habitat code	EUNIS habitats included
Sediment	low/ moderate	littoral	SLL	A2.1, A2.2, A2.3, A2.4, A2.6, A2.7
		infralittoral	SLI	A5.13, A5.23, A5.24, A5.33, A5.34, A5.43
		circalittoral	SLC	A5.13, A5.23, A5.24, A5.33, A5.34, A5.43
	high	littoral	SHL	A2.1, A2.2, A2.4, A2.7
		infralittoral	SHI	A5.13, A5.23, A5.24, A5.33, A5.43
		circalittoral	SHC	A5.14, A5.15, A5.25, A5.26, A5.27, A5.35, A5.44, A5.45
Rock / hard substratum	low/ moderate	littoral	RLL	A1.2, A1.3
		infralittoral	RLI	A3.2, A3.3
		circalittoral	RLC	A4.2, A4.27, A4.3, A4.33
	high	littoral	RHL	A1.1
		infralittoral	RHI	A3.1
		circalittoral	RHC	A4.1, A4.12